ANTENNA MEASUREMENTS: TEST & ANALYSIS OF THE RADIATED EMISSIONS FROM THE NASA/ORION SPACECRAFT ~ PARACHUTE SYSTEM SIMULATOR (Invited Review Paper)

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ABSTRACT

For future NASA Manned Space Exploration of the Moon and Mars, a blunt body capsule, called the Orion Crew Exploration Vehicle (CEV), composed of a Crew Module (CM) and a Service Module (SM), with a parachute decent assembly is planned for reentry back to Earth. A Capsule Parachute Assembly System (CPAS) is being developed for preliminary parachute drop tests at the Yuma Proving Ground (YPG) to simulate high-speed reentry to Earth from beyond Low-Earth-Orbit (LEO) and to provide measurements of landing parameters and parachute loads. The avionics systems on CPAS also provide mission critical firing events to deploy, reef, and release the parachutes in three stages (extraction, drogues, mains) using mortars and pressure cartridge assemblies.

In addition, a Mid-Air Delivery System (MDS) is used to separate the capsule from the sled that is used to eject the capsule from the back of the drop plane. Also, high-speed and high-definition cameras in a Video Camera System (VCS) are used to film the drop plane extraction and parachute landing events.

To verify Electromagnetic Compatibility (EMC) of the CPAS system from unintentional radiation, Electromagnetic Interference (EMI) measurements are being made inside a semi-anechoic chamber at NASA/JSC at 1m from the electronic components of the CPAS system. In addition, EMI measurements of the integrated CPAS system are being made inside a hanger at YPG. These near-field B-Dot probe measurements on the surface of a parachute simulator (DART) are being extrapolated outward to the 1m standard distance for comparison to the MIL-STD radiated emissions limit.

Keywords: NASA, Orion, CEV, CM, SM, CPAS, EMC, EMI, MIL-STD RE

1.0 Introduction

This paper describes EMI/EMC antenna measurements of the new NASA/Orion prototype capsule assembly. NASA's new direction/mission is to maintain the International Space Station (ISS) and to learn to live in space and to return to the Moon and establish a Lunar Habitat on the Moon and learn to live outside the Earth's environment. Later, NASA plans to robotically mine the moon's minerals, to build a Plasma Driven Spaceship on the Moon, and to fly astronauts to Mars.

As shown in Figure 1, the Orion Spacecraft, which will replace the decommissioned Space Shuttle, consists of a Crew Exploration Vehicle (CEV), composed of a Crew Module (CM) and a Service Module (SM), a Launch Abort System (LAS), and a rocket attachment assembly to ride on the top of a heavy-lift launch vehicle into its parking orbit, which will be well beyond low-earth-orbit (LEO).

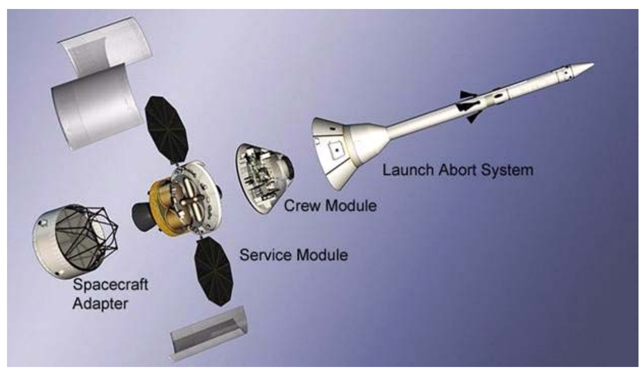

Figure 1 – Orion Spaceship: CEV, CM&SM, LAS, Adapter

The CM of the Orion CEV is a blunt body reentry vehicle that will be slowed on reentry by the Earth's atmospheric drag and will use parachutes for a soft landing in the last stage of decent.

2.0 CPAS (Parachute Drop Tests)

Among other tests conducted at JSC, viz. Thermal/Vac, Vibration/Shock, Acoustics, EMI, etc., the parachute landing system on the Orion CM is being tested for reliability, functionality, and safety in a series of parachute drop tests at the Yuma Proving Ground (YPG).

A Capsule Parachute Assembly System **(**CPAS) is used during the parachute drop tests to provide measurements of position, velocity, acceleration, attitude, temperature, pressure, humidity, and parachute loads. The avionics system in CPAS also provides mission critical firing events to deploy, reef, and release parachutes in three (3) stages (extraction, drogues, mains) using mortars and pressure cartridge assemblies (PCAs), initiated with NASA Standard Initiators (NSIs).

3.0 Orion Testing

The LAS is being tested at the White Sands Missile Range (WSMR) during a series of live firings. The external phased array antennas on the CEV CM/SM capsules are being tested in the Anechoic Chamber at JSC for antenna placements for space-to-space and space-to-Earth communications. In addition, MIL-STD EMI tests of the unshielded internal CPAS components are being performed in the Semi-Anechoic Chamber at JSC. All parachute drop tests are being conducted at YPG.

Individually shielded CPAS components mounted on a test sled, called the DART (which will fit inside a C130), is being tested to simulate the advanced behavior of the CM on an actual reentry.

To assure Safety-of-Flight (SoF) for the parachute drop planes, preliminary EMI tests are also being performed at YPG before the parachute drop tests are actually conducted.

4.0 CEV Tests

The CEV tests performed at JSC (external antenna placement tests in the anechoic chamber and internal unshielded CPAS component tests in the semi-anechoic chamber) and the shielded DART CPAS component tests conducted at YPG are described below.

4.1 NASA/JSC Tests

4.1.1 Anechoic Chamber Tests (Phased Array Antenna ~ External Placement Test)

The CEV CM/SM combination is being tested for proper antenna array placement. Figure 2a shows the Orion CEV Capsule in orbit. Figure 2b shows the combined CM/SM prototype on its test stand in the JSC Anechoic Chamber. Figure 2c shows the CM being tested on the pedestal tower. This prototype is a full-scale AL mockup of the external details/characteristics of the CM/SM capsules.

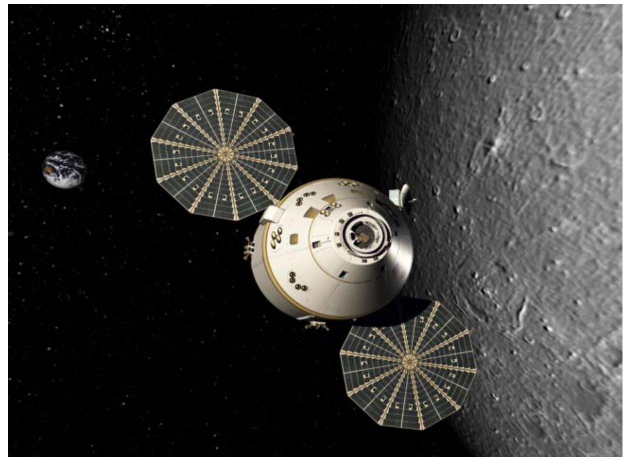

Figure 2a – Orion CEV Capsule (on Orbit)

Figure 2b - CM/SM Prototype (on Test Stand)

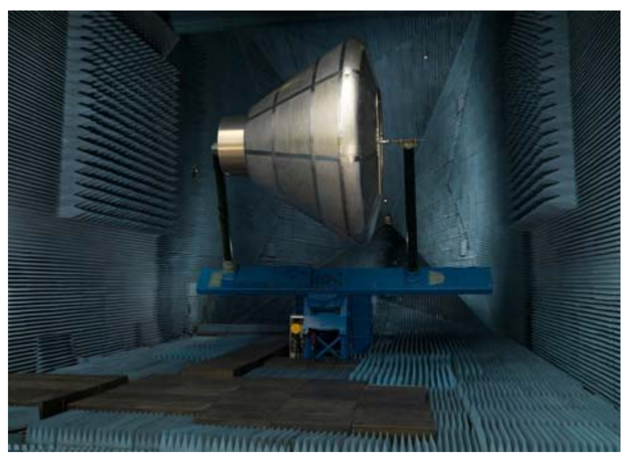

Figure 2c – CM Prototype (on Test Tower)

4.1.2 Semi-Anechoic Chamber Tests (MIL-STD Tests ~ Unshielded Internal Components)

The test setup for CPAS is shown in Figure 3.

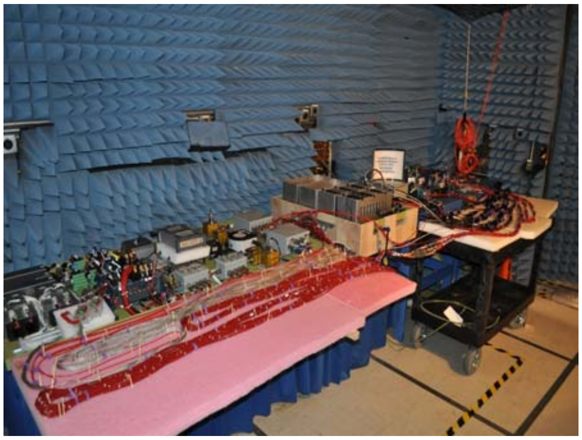

Figure 3 – CPAS Extended Test Layout/Setup

The test procedures, test setups (frequencies, bandwidths, polarizations), equipment, limits, etc. are from MIL-STDs 461 and 462.

CPAS was tested from (in Horizontal/Vertical Polarizations) : [See Figures 4(a-d)]

2-30 MHz (VP)
30-200 MHz (HP/VP)
200-1000 MHz (HP/VP)
1-10 GHz, 11.5-15.5 GHz (HP/VP)

CPAS failed the initial MIL-STD radiated emissions test in the 200 MHz – 1 GHz frequency range. The non-compliances in this frequency range are shown in Figure 5.

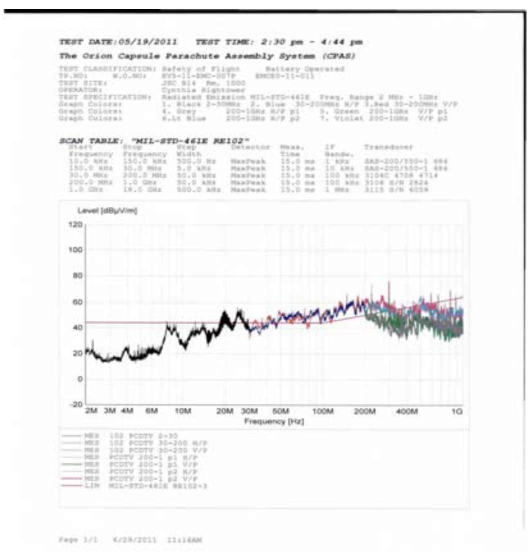

Figure 5 – CPAS Non-Compliances (Unshielded Component Trays)

Figure 4a – CPAS Test Setup (2-30 MHz) Unshielded (VP)

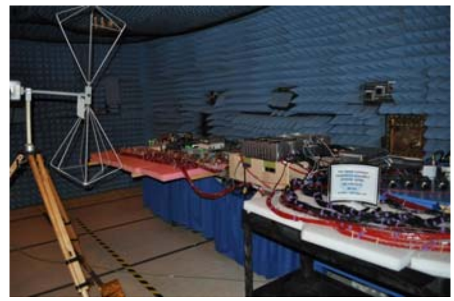

Figure 4b – CPAS Test Setup (30-200 MHz) Unshielded (HP/VP ~ VP shown)

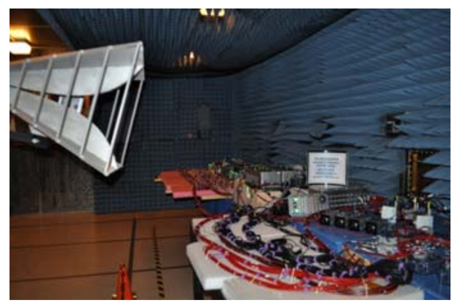

Figure 4c – CPAS Test Setup (30-1000 MHz) Unshielded (HP/VP ~ VP shown)

Figure 4d – CPAS Test Setup (1-15.5 GHz) Unshielded (HP/VP ~ VP shown)

After the EMI test failure, the cables and components of CPAS were shielded by wrapping them in AL foil, as shown in Figures 6(a&b). The MIL-STD radiated emissions test was rerun in the 200 MHz – 1 GHz frequency range, as shown in Figure 7. The new test results are shown in Figure 8.

Figure 6a – CPAS Shielded Cables

Figure 6b – CPAS Shielded Components

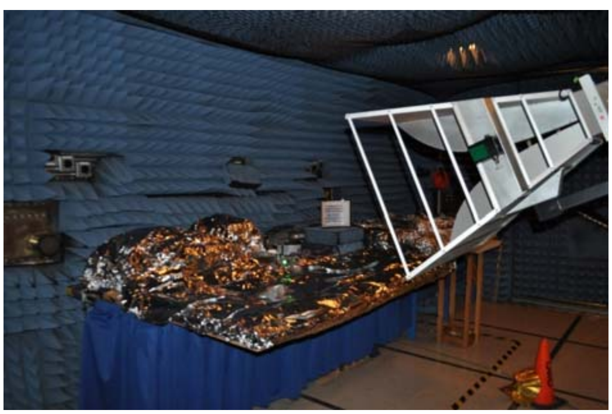

Figure 7 – CPAS Test Setup (200-1000 MHz) Shielded (HP/VP ~ VP shown) Retest

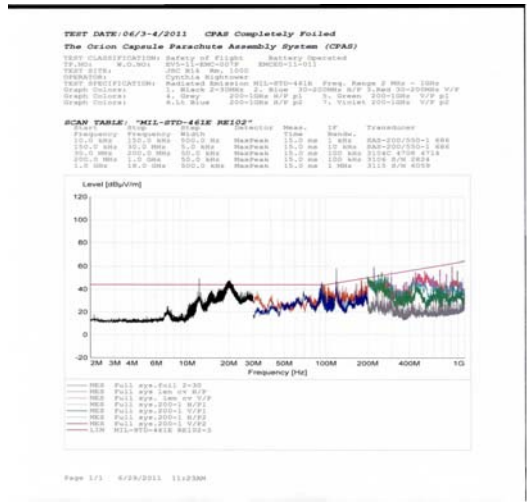

Figure 8 – CPAS Non-Compliances (Shielded CPAS Components)

The shielding of the cables and components of CPAS greatly reduced the EMI non-compliances to a few low-intensity, narrow-band spikes across the 20 MHz - 1 GHz frequency range.

Therefore, a more permanent shielded enclosure (Faraday cage) for the CPAS tray was constructed, as shown in Figure 9, for the future hanger and drop tests at YPG.

Figure 9 – Primary&Secondary Avionics Trays (Metal Sides, Conductive Cloth Cover, Mesh Window)

4.2 YPG CPAS/DART Simulator Drop Tests

The CPAS drop test system consists of a DART Simulator. The DART Simulator was tested in a hanger at YPG.

The DART simulator, pictured in Figures 10(a-d), consists of a Parachute Capsule Delivery Test Vehicle (PCDTV), a Mid Air Delivery System (MDS), and a Video Camera System (VCS: multiple high-definition and high-speed cameras).

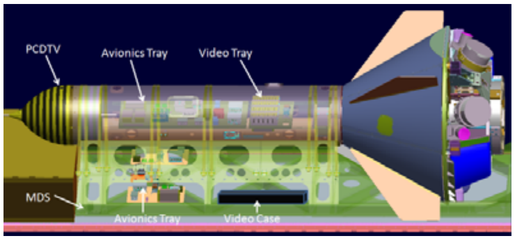

Figure 10a – DART Drop Test Simulator Schematic

Figure 10b – DART Drop Test Simulator (Before MDS and Parachute Loading)

Figure 10c – DART Drop Test Simulator (After MDS and Parachute Loading)

Figure 10d – DART Drop Test Simulator (Parachute Compartment)

The Avionics Trays, in the shape of shielded rectangular bays, fit inside the framework of the CPAS. The CPAS cameras were used during the parachute drop tests to provide close-up views of parachute deployments, platform motion, vehicle motion, and steady-state parachute dynamics.

4.1.2.1 YPG DART Hanger Tests

The test procedures, test setups, equipment, limits, etc., are from MIL-STDs 461 and 462.

To measure the radiated emissions from the PCDTV, MDS, and VCA trays, a B-Dot probe was scanned over the various aperture locations around the DART.

4.1.2.2 YPG B-Dot Probe Field Tests

After the B-Dot probe was setup at each location, the received power was measured with a Spectrum Analyzer (S/A).

Assuming that the probe was electrically small, the power in the probe was measured and converted analytically into an equivalent magnetic field intensity. The aperture plane was extrapolated outward to the 1m transverse plane, the distance at which the MIL-STD radiated emissions limit apply.

4.1.2.3 YPG DART Simulator Radiated Emissions

As a single, but typical, example of the radiated emissions from the equipment on the Avionics Tray, the radiated emissions from the unshielded cRIO component are shown in Figure 11a; the radiated emissions from the shielded cRIO component are shown in Figure 11b. All the frequency components were non-compliant for the unshielded case; only one frequency component was non-compliant for the shielded case.

4.1.2.4. CPAS/DART Simulator Drop Tests

After the SoF verification, the DART Simulator was loaded into a C130 drop plane, as shown in Figure 12a. Figure 12b shows the release/extraction of the DART Simulator. Figure 12c shows the drop test with only two (2) of the three (3) chutes opening to simulate a 1 chute firing failure and resulting high-impact G-forces on landing. Figure 12d shows the DART Simulator after a relatively smooth landing.

4.2.2 Future Work: CPAS Prototype Capsule Simulator

A new Orion prototype capsule simulator is now being designed, built, and tested at YPG.

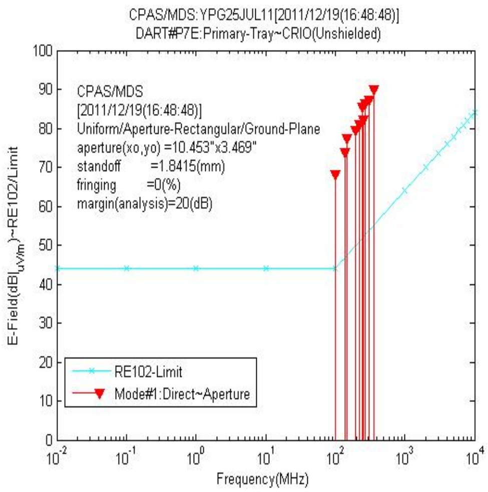

Figure 11a – DART/CRIO (Unshielded) Avionics Tray

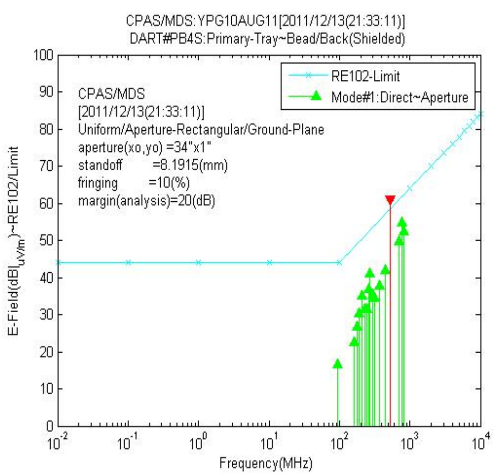

Figure 11b – DART/cRIO (Shielded) Avionics Tray

5. Summary/Conclusions

The new cloth shielding material is forming a good flexible shield over the trays and is attenuating the radiated emissions from the components on the trays, as required. Most of the lower frequency (~200-400 MHz) radiated emissions are attenuated close to the MIL-STD radiated emissions limit. However, as also noted earlier, the HD cameras, which are not completely shielded, produce radiated emissions higher than the limit.

The permanent shield of the PCDTV components worked well and the radiated emissions, with few exceptions, passed the SoF tests.

6. References

[1] MIL-STD 461
[2] MIL-STD 462

Figure 12a – DART C130 Loading

Figure 12b – DART C130 Release/Extraction

Figure 12c – DART Drop (2 Chutes out of 3 Simulating a 1 Chute Firing Failure)

Figure 12d – DART Landing: Recovery/Repair/Refurbish/Reuse